June 2001

Chemistry 30

Grade 12 Diploma Examination

Alberta
LEARNING

June 2001

Chemistry 30

Grade 12 Diploma Examination

Description

Time: This examination was developed to be completed in 2.5 h; however, you may take an additional 0.5 h to complete the examination.

This is a **closed-book** examination consisting of

- 44 multiple-choice and 12 numerical-response questions of equal value, worth 70% of the examination
- 2 written-response questions of equal value, worth 30% of the examination

This examination contains sets of related questions.

A set of questions may contain multiple-choice and/or numerical-response and/or written-response questions.

When required, a grey bar will be used to indicate the end of a set.

A chemistry data booklet is provided for your reference.

Note: *The perforated pages at the back of this booklet may be torn out and used for your rough work.* ***No marks*** *will be given for work done on the tear-out pages.*

Instructions

- You are expected to provide your own calculator. You may use any scientific calculator or a graphing calculator approved by Alberta Learning.
- You are expected to have cleared your calculator of all information that is stored in the programmable or parametric memory.
- Use only an HB pencil for the machine-scored answer sheet.
- Fill in the information required on the answer sheet and the examination booklet as directed by the presiding examiner.
- Read each question carefully.
- Consider all numbers used in the examination to be the result of a measurement or observation.
- When performing calculations, use the values of the constants provided in the data booklet. Do **not** use the values programmed in your calculator.
- If you wish to change an answer, erase **all** traces of your first answer.
- Do not fold the answer sheet.
- The presiding examiner will collect your answer sheet and examination booklet and send them to Alberta Learning.
- Now turn this page and read the detailed instructions for answering machine-scored and written-response questions.

Multiple Choice

- Decide which of the choices **best** completes the statement or answers the question.
- Locate that question number on the separate answer sheet provided and fill in the circle that corresponds to your choice.

Example

This examination is for the subject of

A. chemistry
B. biology
C. physics
D. science

Answer Sheet

● Ⓑ Ⓒ Ⓓ

Numerical Response

- Record your answer on the answer sheet provided by writing it in the boxes and then filling in the corresponding circles.
- If an answer is a value between 0 and 1 (e.g., 0.25), then be sure to record the 0 before the decimal place.
- **Enter the first digit of your answer in the left-hand box and leave any unused boxes blank.**

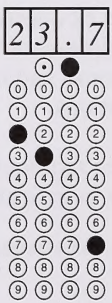
Examples

Calculation Question and Solution

The average of the values 21.0, 25.5, and 24.5 is _____.
(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Average = (21.0 + 25.5 + 24.5)/3
= 23.666
= 23.7 (rounded to three digits)

Record 23.7 on the answer sheet →



Correct-Order Question and Solution

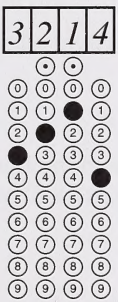
When the following subjects are arranged in alphabetical order, the order is ____ , ____ , ____ , and ____ .

1 physics
2 chemistry
3 biology
4 science

(Record your **four-digit answer** in the numerical-response section on the answer sheet.)

Answer 3214

Record 3214 on the answer sheet →



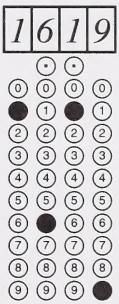
Scientific Notation Question and Solution NEW

The charge on an electron is $-a.b \times 10^{-cd}$ C. The values of a, b, c, and d are ____, ____, ____, and ____ .

(Record your **four-digit answer** in the numerical-response section on the answer sheet.)

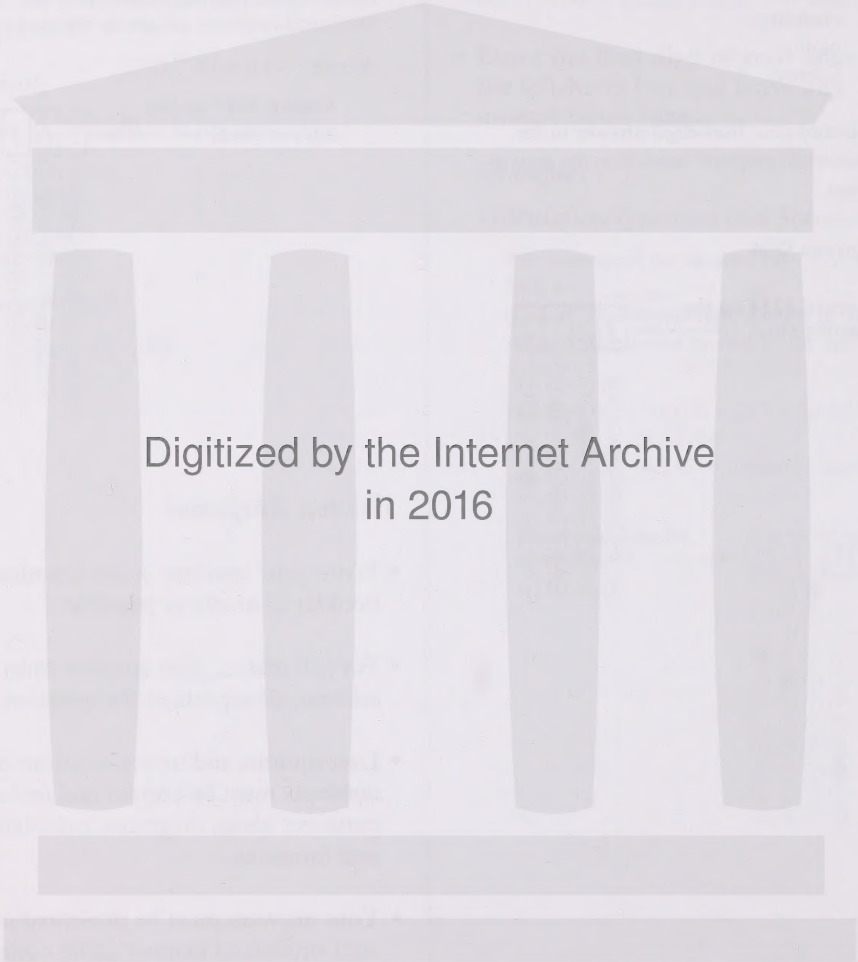
Answer: -1.6×10^{-19} C

Record 1619 on the answer sheet →



Written Response

- Write your answers in the examination booklet as neatly as possible.
- For full marks, your answers must address **all** aspects of the question.
- Descriptions and/or explanations of concepts must be correct and include pertinent ideas, diagrams, calculations, and formulas.
- Your answers must be presented in a well-organized manner using complete sentences, correct units, and significant digits where appropriate.
- Relevant scientific, technological, and/or societal concepts and examples must be identified and made explicit.



1. Which of the following equations is associated with the largest energy change per mole of fluorine?

A. $F_{2(g)} \rightarrow F_{2(l)}$

B. $^{19}_{9}F + {}^{4}_{2}He \rightarrow {}^{1}_{0}n + {}^{22}_{11}Na$

C. $2\,F_{2(g)} + 2\,H_2O_{(l)} \rightarrow O_{2(g)} + 4\,HF_{(aq)}$

D. $CH_{4(g)} + 2\,Cl_{2(g)} + 2\,F_{2(g)} \rightarrow CCl_2F_{2(g)} + 2\,HCl_{(g)} + 2\,HF_{(g)}$

2. Which of the following molecular properties is a main component of the potential energy of matter?

A. Vibrational motion

B. Intramolecular bonding

C. Movement from place to place

D. Rotation about the molecules' centre of mass

3. When one mole of sodium bicarbonate is formed from its elements, 947.7 kJ of heat energy is released into the surroundings. This enthalpy change can be represented as

A. $Na_{(s)} + \frac{1}{2}H_{2(g)} + C_{(s)} + \frac{3}{2}O_{2(g)} \rightarrow NaHCO_{3(s)} + 947.7\ kJ$

B. $Na_{(s)} + \frac{1}{2}H_{2(g)} + C_{(s)} + \frac{3}{2}O_{2(g)} + 947.7\ kJ \rightarrow NaHCO_{3(s)}$

C. $Na^{+}_{(aq)} + HCO_3^{-}{}_{(aq)} \rightarrow NaHCO_{3(s)} + 947.7\ kJ$

D. $Na^{+}_{(aq)} + HCO_3^{-}{}_{(aq)} + 947.7\ kJ \rightarrow NaHCO_{3(s)}$

Use the following information to answer the next question.

Cold packs are commonly used by athletes to reduce swelling caused by injury. The packs consist of two plastic pouches: an inner pouch that contains a chemical and an outer pouch that contains water. When the inner pouch is broken, the chemical and water mix, which causes the pack to feel cold.

Statements

1 Ice is considerably less expensive than are commercial cold packs.

2 Ammonium nitrate is commonly used in cold packs because its heat of solution is endothermic.

3 The disposal of cold packs poses a landfill concern.

4 Durability and flexibility are design requirements for the plastic outer pouch.

—from *Nelson Chemistry,* 1st edition

Numerical Response

1. The statements above that reflect an ecological, scientific, economic, and technological perspective are, respectively, _____ , _____ , _____ , and _____ .

(Record your **four-digit answer** in the numerical-response section on the answer sheet.)

Numerical Response

2. The energy released when 1.00 mol of $AgI_{(s)}$ is formed from its elements is _____ kJ.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Use the following information to answer the next two questions.

Glucose is a biological fuel used by cells to satisfy the energy needs of plants and animals. The overall reaction for the metabolism of glucose is represented by the **unbalanced** equation

$$\_\_C_6H_{12}O_{6(s)} + \_\_O_{2(g)} \rightarrow \_\_CO_{2(g)} + \_\_H_2O_{(l)}$$

4. The balanced equation and the enthalpy change for the cellular respiration of glucose can be represented as

A. $C_6H_{12}O_{6(s)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(l)} + 593.8\ kJ$

B. $C_6H_{12}O_{6(s)} + 6\,O_{2(g)} + 2\,802.7\ kJ \rightarrow 6\,CO_{2(g)} + 6\,H_2O_{(l)}$

C. $C_6H_{12}O_{6(s)} + 6\,O_{2(g)} \rightarrow 6\,CO_{2(g)} + 6\,H_2O_{(l)} + 2\,802.7\ kJ$

D. $C_6H_{12}O_{6(s)} + 6\,O_{2(g)} \rightarrow 6\,CO_{2(g)} + 6\,H_2O_{(l)} + 2\,538.7\ kJ$

5. If solid glucose is completely burned in the flame of a Bunsen burner, the enthalpy change is

A. greater than it is during cellular respiration because the production of $H_2O_{(g)}$ releases more energy than does the production of $H_2O_{(l)}$

B. less than it is during cellular respiration because the production of $H_2O_{(g)}$ releases less energy than does the production of $H_2O_{(l)}$

C. the same as it is in the body because the enthalpy change is independent of the state of the products

D. the same as it is in cellular respiration because they are identical processes

6. When 1.65 g of ethanal ($CH_3CHO_{(l)}$) is burned in a calorimeter to produce $H_2O_{(l)}$ and $CO_{2(g)}$, 44.7 kJ of heat energy is produced. According to this experimental data, the molar enthalpy of combustion of ethanal is

A. $+1.52 \times 10^3$ kJ/mol

B. –76.6 kJ/mol

C. –165 kJ/mol

D. -1.19×10^3 kJ/mol

Numerical Response

3. A student heated a 120.0 g sample of $H_2O_{(l)}$ from 21.0°C to 32.5°C by adding 5.93 kJ of energy. The student then used this data to calculate the specific heat capacity of water and compared it with the standard value. The experimental percentage difference was _____ %.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Use the following equation to answer the next question.

$$2\,C_2H_{2(g)} + 5\,O_{2(g)} \rightarrow 4\,CO_{2(g)} + 2\,H_2O_{(g)} \qquad \Delta H = -2\,511.0\ \text{kJ}$$

Numerical Response

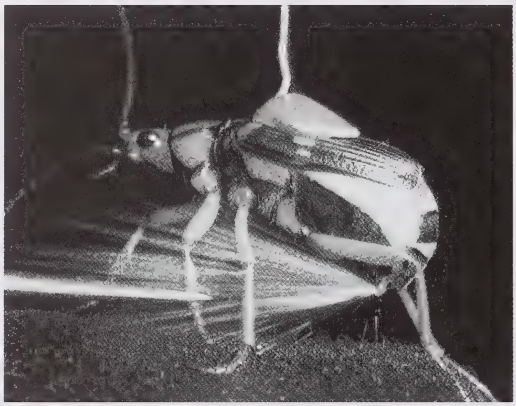
4. The amount of energy released by the combustion of 100 g of $C_2H_{2(g)}$ is _____ MJ.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Use the following information to answer the next question.

Many insects and small animals have unique defence systems. Bombardier beetles fight off predators with a hot chemical spray. This spray consists of solutions of hydroquinone ($C_6H_4(OH)_{2(aq)}$), hydrogen peroxide ($H_2O_{2(aq)}$), and enzymes, which are secreted by the beetles' glands.

Bombardier Beetle



—from *Chemistry,* Fifth Edition

Reaction Equations Related to Spray Formation

I $2\,H_2O_{(l)} + O_{2(g)} \rightarrow 2\,H_2O_{2(aq)}$ $\Delta H = +189.2$ kJ

II $H_2O_{(l)} \rightarrow H_{2(g)} + \frac{1}{2}\,O_{2(g)}$ $\Delta H = +285.8$ kJ

III $C_6H_4(OH)_{2(aq)} \rightarrow C_6H_4O_{2(aq)} + H_{2(g)}$ $\Delta H = +177.0$ kJ

A chemical reaction that occurs in order to produce the hot chemical spray can be represented by the equation

$$\underset{\text{hydroquinone}}{C_6H_4(OH)_{2(aq)}} + H_2O_{2(aq)} \rightarrow \underset{\text{quinone}}{C_6H_4O_{2(aq)}} + 2\,H_2O_{(l)}$$

7. The heat of reaction for the production of this hot chemical spray is

A. -489.2 kJ

B. -203.4 kJ

C. -82.4 kJ

D. $+12.2$ kJ

Use the following equations to answer the next question.

Energy Reaction Equations

I $C_6H_{12}O_{6(aq)} + 6\,O_{2(g)} \rightarrow 6\,CO_{2(g)} + 6\,H_2O_{(l)} + \text{energy}$

II ${}^{1}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + \text{energy}$

III $6\,CO_{2(g)} + 6\,H_2O_{(l)} + \text{energy} \rightarrow C_6H_{12}O_{6(aq)} + 6\,O_{2(g)}$

8. The energy reactions above involve the conversion of energy for metabolic (body) processes. The chronological order of these reactions is

A. I, III, and II

B. III, II, and I

C. II, III, and I

D. II, I, and III

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9. The total enthalpy change associated with the conversion of 1.00 Mg of water at 20.0°C into steam at 250.0°C could be calculated by using the formula

A. [1.00 Mg × 4.19 J/(g • °C) × 80.0°C] + [(1.00 Mg/18.02 g/mol) × 40.8 kJ/mol]

B. [1.00 Mg × 2.01 J/(g • °C) × 230.0°C] + [(1.00 Mg/18.02 g/mol) × 40.8 kJ/mol]

C. [1.00 Mg × 4.19 J/(g • °C) × 80.0°C] + [(1.00 Mg/18.02 g/mol) × 40.8 kJ/mol] + [1.00 Mg × 4.19 J/(g • °C) × 150.0°C]

D. [1.00 Mg × 4.19 J/(g • °C) × 80.0°C] + [(1.00 Mg/18.02 g/mol) × 40.8 kJ/mol] + [1.00 Mg × 2.01 J/(g • °C) × 150.0°C]

At the Wascana Gas Plant in Balzac, Alberta, environmental and economic concerns have resulted in the development of an efficient process for the removal of sulphur from sour gas, which is a mixture of hydrocarbons and $H_2S_{(g)}$. In the first step of the process, one-third of the $H_2S_{(g)}$ reacts with $O_{2(g)}$ to produce $SO_{2(g)}$. In the second step of the process, the $SO_{2(g)}$ produced reacts with the remaining $H_2S_{(g)}$ to form elemental sulphur and water.

Step I	$2\,H_2S_{(g)} + 3\,O_{2(g)} \rightleftharpoons 2\,H_2O_{(g)} + 2\,SO_{2(g)}$
Step II	$2\,H_2S_{(g)} + SO_{2(g)} \rightleftharpoons 2\,H_2O_{(g)} + 3\,S_{(s)}$
Overall equation	$2\,H_2S_{(g)} + O_{2(g)} \rightleftharpoons 2\,H_2O_{(g)} + 2\,S_{(s)}$

To maximize the amount of sulphur removed from the sour gas, the gas plant engineers apply Le Châtelier's principle.

10. According to the overall equilibrium equation above, the amount of sulphur removed may be increased by

A. adding a catalyst
B. removing water vapour
C. increasing the volume of the system
D. increasing the temperature of the system

11. As $H_2S_{(g)}$ forms $S_{(s)}$, the oxidation number of sulphur

A. changes from 0 to –2 and sulphur is reduced
B. changes from –2 to 0 and sulphur is oxidized
C. decreases by 2 and hydrogen sulphide acts as the reducing agent
D. stays the same because the sulphur is neither oxidized nor reduced

Use the following information to answer the next question.

The sulphur produced in step II is initially produced in liquid form. As it cools, it is converted from a liquid state to a solid state as represented by the equation

$$S_{(l)} \rightarrow S_{(s)}$$

12. In terms of energy, this conversion is

A. endothermic, releases heat, and has a positive ΔH

B. exothermic, releases heat, and has a negative ΔH

C. exothermic, absorbs heat, and has a negative ΔH

D. endothermic, absorbs heat, and has a positive ΔH

At one time, an aqueous solution of formaldehyde called formalin ($CH_2O_{(aq)}$) was used as a disinfectant and as a tissue preservative. Today, formalin is commonly used in the industrial preparation of plastics and resins.

Formalin can be produced by reacting methanol with acidified potassium dichromate, as represented by the following **unbalanced** equation.

$$\_CH_3OH_{(l)} + \_Cr_2O_7^{2-}{}_{(aq)} + \_H^+{}_{(aq)} \rightarrow \_CH_2O_{(aq)} + \_Cr^{3+}{}_{(aq)} + \_H_2O_{(l)}$$

13. The type of reaction that this equation represents is

A. a Brønsted–Lowry acid–base reaction
B. an oxidation–reduction reaction
C. a formation reaction
D. a combustion reaction

14. When the above equation is balanced, the equation is

A. $CH_3OH_{(l)} + Cr_2O_7^{2-}{}_{(aq)} + 14\,H^+{}_{(aq)} \rightarrow CH_2O_{(aq)} + 2\,Cr^{3+}{}_{(aq)} + 7\,H_2O_{(l)}$

B. $3\,CH_3OH_{(l)} + Cr_2O_7^{2-}{}_{(aq)} + 14\,H^+{}_{(aq)} \rightarrow 3\,CH_2O_{(aq)} + 2\,Cr^{3+}{}_{(aq)} + 7\,H_2O_{(l)}$

C. $3\,CH_3OH_{(l)} + Cr_2O_7^{2-}{}_{(aq)} + 8\,H^+{}_{(aq)} \rightarrow 3\,CH_2O_{(aq)} + 2\,Cr^{3+}{}_{(aq)} + 7\,H_2O_{(l)}$

D. $3\,CH_3OH_{(l)} + Cr_2O_7^{2-}{}_{(aq)} + 8\,H^+{}_{(aq)} \rightarrow 3\,CH_2O_{(aq)} + 2\,Cr^{3+}{}_{(aq)} + 8\,H_2O_{(l)}$

*Use your recorded answer for **Multiple Choice 14** to answer **Numerical Response 5.****

Numerical Response

5. When 39.5 kg of methanol is reacted, the mass of formalin produced is _____ kg.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

***You can receive marks for this question even if the previous question was answered incorrectly.**

15. Iodine solutions, which contain a suspension of $I_{2(s)}$, have a brown colour. Which of the following metals will **not** cause an iodine solution to change colour?

A. $Ni_{(s)}$

B. $Cu_{(s)}$

C. $Ag_{(s)}$

D. $Mg_{(s)}$

Use the following information to answer the next question.

A sample of $Na_2S_2O_{3(aq)}$ is titrated with acidified $KMnO_{4(aq)}$ to a pink endpoint. One product of this redox reaction is $SO_4^{2-}{}_{(aq)}$.

16. A product of the reduction half-reaction is

A. $H^+_{(aq)}$

B. $Mn^{2+}_{(aq)}$

C. $SO_4^{2-}{}_{(aq)}$

D. $S_2O_3^{2-}{}_{(aq)}$

Use the following information to answer the next question.

In an experiment, dilute hydrochloric acid was added to a test tube containing several small pieces of zinc metal.

17. Which of the following observations could have been made during this experiment?

A. There was no reaction.

B. A thick white precipitate formed.

C. A colourless gas was produced and the test tube cooled off.

D. A colourless gas was produced and the test tube warmed up.

Use the following information to answer the next question.

A student used an acidified 6.31×10^{-2} mol/L $KMnO_{4(aq)}$ solution to titrate 25.0 mL samples of $Fe^{2+}_{(aq)}$ solution of unknown concentration. In the reactions, the $Fe^{2+}_{(aq)}$ ion was oxidized to the $Fe^{3+}_{(aq)}$ ion. The student completed five trials and summarized the data in a table.

Trial Number	1	2	3	4	5
Final Buret Reading (mL)	17.55	35.65	26.40	42.65	16.85
Initial Buret Reading (mL)	0.30	17.55	10.05	26.40	0.55
Final Colour	purple	purple	pink	pink	pink

18. According to the student's data, the concentration of $Fe^{2+}_{(aq)}$ is

A. 0.206 mol/L
B. 0.218 mol/L
C. 0.213 mol/L
D. 0.223 mol/L

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19. The half-reaction to which all other half-cell potentials are compared is

A. $Li^{+}_{(aq)} + e^{-} \rightarrow Li_{(s)}$
B. $Au^{3+}_{(aq)} + 3e^{-} \rightarrow Au_{(s)}$
C. $F_{2(g)} + 2e^{-} \rightarrow 2F^{-}_{(aq)}$
D. $2H^{+}_{(aq)} + 2e^{-} \rightarrow H_{2(g)}$

Use the following information to answer the next two questions.

Electronic hobbyists often "etch" circuit boards. In this process, unwanted copper foil is removed from a copper-clad plastic circuit board by immersing the board in a bath of iron(III) chloride solution. The equation for the net reaction is

$$Cu_{(s)} + 2\,Fe^{3+}_{(aq)} \rightarrow Cu^{2+}_{(aq)} + 2\,Fe^{2+}_{(aq)}$$

20. In the reaction above, in which the unwanted copper foil is removed,

A. copper ions are reduced

B. copper atoms are oxidized

C. iron(II) ions act as the oxidizing agent

D. iron(III) ions act as the reducing agent

21. Which of the following statements and corresponding net voltages are correct for this reaction?

A. It is a spontaneous reaction with an $E^{\circ}_{net} = +0.43$ V.

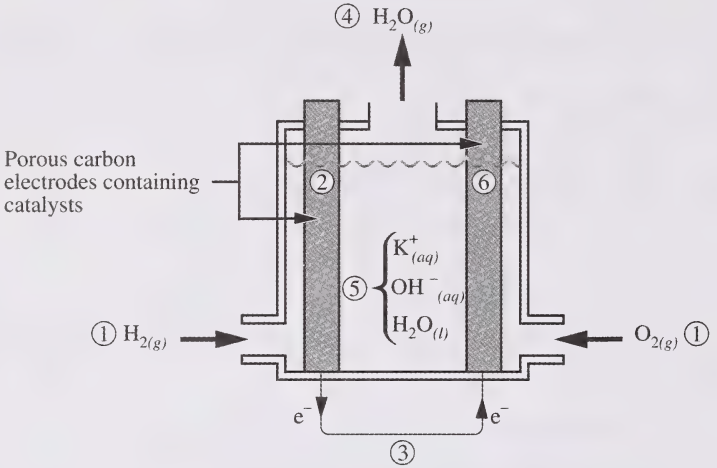
B. It is a spontaneous reaction with an $E^{\circ}_{net} = +1.11$ V.

C. A power supply is required because the $E^{\circ}_{net} = -0.43$ V.

D. A power supply is required because the $E^{\circ}_{net} = -1.11$ V.

Use the following information to answer the next two questions.

Hydrogen–oxygen fuel cells have been used for years in spacecraft and more recently in small-scale power plants to generate electricity. Now, some governments and companies are working together to perfect this type of fuel cell for automobile use, and experiments are currently being conducted with operational prototypes. A diagram of a hydrogen–oxygen fuel cell is shown below.



Numerical Response

6. In the diagram above, the anode, the cathode, the electrolyte, and a product of the reaction are labelled, respectively, _____ , _____ , _____ , and _____ .

(Record your **four-digit answer** in the numerical-response section on the answer sheet.)

22. From an ecological perspective, a reason why hydrogen–oxygen fuel cells should **not** be used to power automobiles is that

A. hydrogen fuel can be produced through the electrolysis of seawater by using the energy produced from burning fossil fuels

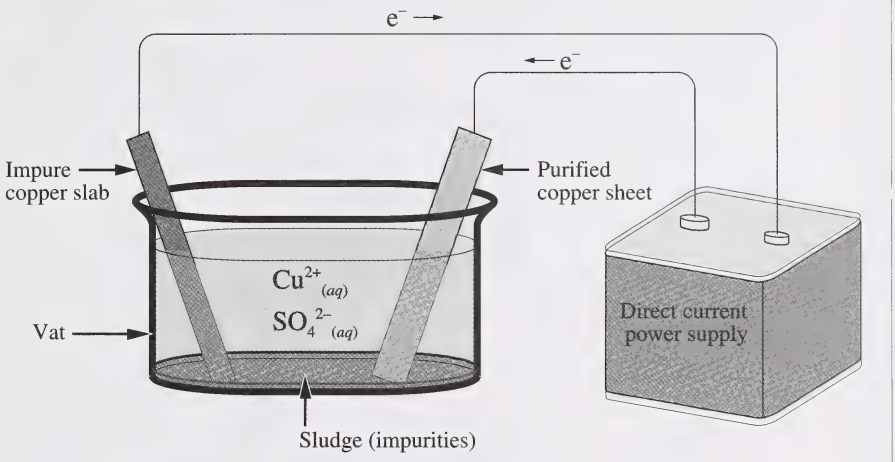
B. cars powered by a hydrogen–oxygen fuel cell would be up to 30% more efficient than cars powered by gasoline

C. water vapour is the primary byproduct of the cell

D. oxygen is readily available from the atmosphere

Use the following diagram to answer the next two questions.

Copper can be refined (purified) using an apparatus like the one shown below, which is a small-scale version of an industrial apparatus.



23. In this electrochemical cell, the purified copper sheet acts as the

A. anode and is the site where $SO_4^{2-}{}_{(aq)}$ ions are oxidized

B. cathode and is the site where $SO_4^{2-}{}_{(aq)}$ ions are reduced

C. anode and is the site where $Cu^{2+}{}_{(aq)}$ ions are oxidized

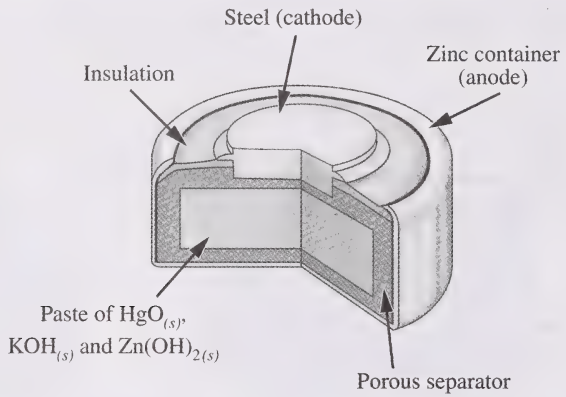
D. cathode and is the site where $Cu^{2+}{}_{(aq)}$ ions are reduced

Numerical Response

7. If the direct current power supply produces a steady 3.50 A current, then the time required to deposit 0.100 g of purified copper is _____ s.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

The silver oxide alkaline cell is a miniature power source used in watches, calculators, hearing aids, and cameras. The construction of this cell is shown in the following diagram.



Half-Reactions

$$Zn(OH)_{2(s)} + 2e^- \rightarrow Zn_{(s)} + 2OH^-_{(aq)} \qquad E° = -1.25 \text{ V}$$

$$Ag_2O_{(s)} + H_2O_{(l)} + 2e^- \rightarrow 2Ag_{(s)} + 2OH^-_{(aq)} \qquad E° = +0.34 \text{ V}$$

24. During the discharging of the cell, the substance oxidized is

A. $Zn_{(s)}$

B. $Ag_{(s)}$

C. $H_2O_{(l)}$

D. $Ag_2O_{(s)}$

25. In this cell, the separator must be porous in order to

A. allow migration of ions

B. replenish the electrolyte

C. provide a pathway for electron flow

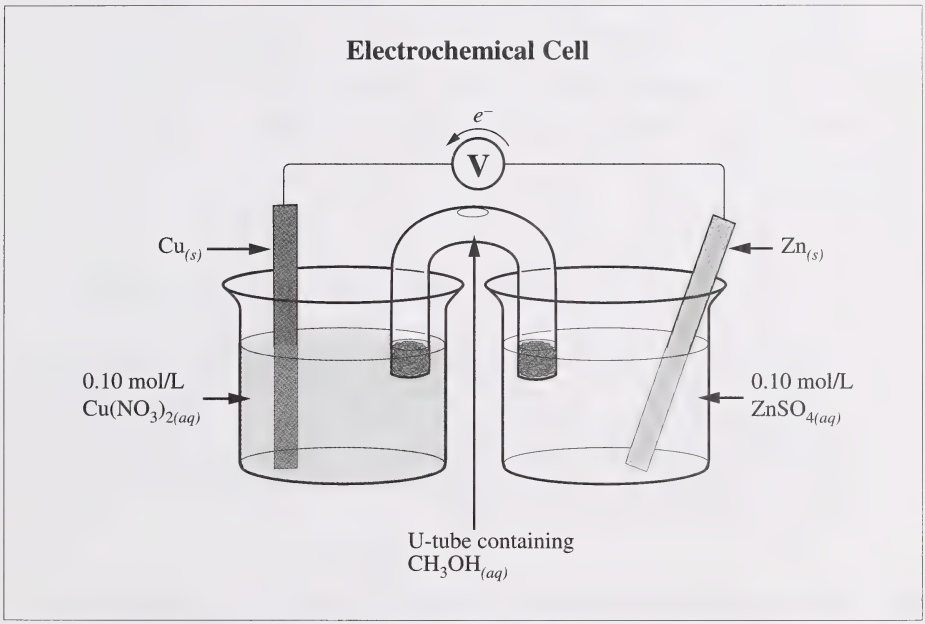
D. provide a surface on which electron transfer can occur

Numerical Response

8. During discharge, the voltage generated by the cell is +/–_____ V.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Use the following diagram to answer the next question.



26. The cell in the diagram was constructed and connected by a chemistry student. The voltage of the cell remained at 0.00 V trial after trial. One possible reason for the malfunction of the cell was that the

A. concentrations of the solutions were too low

B. solution in the U-tube was a non-electrolyte

C. redox reaction was non-spontaneous

D. voltmeter was connected backward

Use the following information to answer the next question.

Kawneer, a company in Lethbridge, processes aluminum "logs" for commercial use. The first step in the process involves removing the natural aluminum oxide coating from the logs.

27. Once the protective coating has been removed, the $Al_{(s)}$ surface undergoes a redox reaction with $H_2O_{(l)}$. In this reaction,

A. $H_{2(g)}$ is evolved and the solution becomes basic

B. $O_{2(g)}$ is evolved and the solution becomes basic

C. $H_{2(g)}$ is evolved and the solution becomes acidic

D. $O_{2(g)}$ is evolved and the solution becomes acidic

Use the following information to answer the next question.

In the late 1980s, the Canadian dollar bill was replaced by a coin commonly called the "loonie." The loonie is manufactured from nickel disks that are stamped and then coated with a thin layer of copper (87.5%) and tin (12.5%) to provide the shiny gold-coloured appearance. This layer is applied through an electrolysis process in which the stamped loonie is one of the electrodes and copper metal is the other electrode.

28. If the plating of the loonie occurs in a $Sn^{2+}_{(aq)}$ and $Cu^{2+}_{(aq)}$ solution, then the reaction that occurs at the cathode is

A. $2\,H_2O_{(l)} + 2\,e^- \rightarrow H_{2(g)} + 2\,OH^-_{(aq)}$

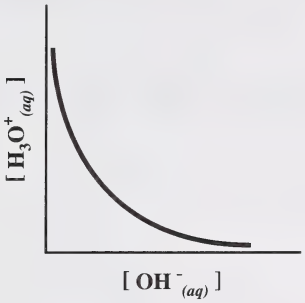
B. $2\,H_2O_{(l)} \rightarrow O_{2(g)} + 4\,H^+_{(aq)} + 4\,e^-$

C. $Cu^{2+}_{(aq)} + 2\,e^- \rightarrow Cu_{(s)}$

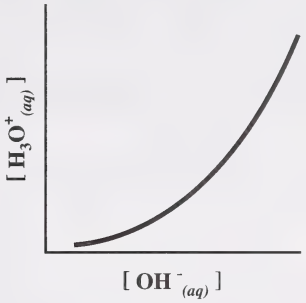
D. $Cu_{(s)} \rightarrow Cu^{2+}_{(aq)} + 2\,e^-$

29. Of the graphs below, the one that best illustrates the relationship between $[H_3O^+_{(aq)}]$ and $[OH^-_{(aq)}]$ in a solution is

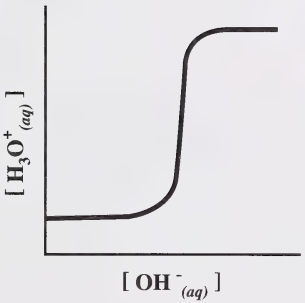
A.



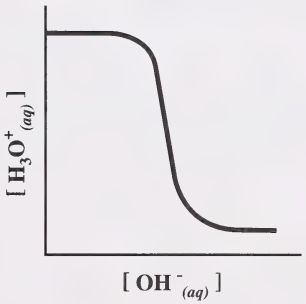
B.



C.



D.



30. If equal moles of acid and base are mixed, then which of the following pairs of species yields a solution with a pH closest to that of pure water at 25°C?

A. $HSO_4^-{}_{(aq)}$ and $OH^-_{(aq)}$

B. $H_2S_{(aq)}$ and $OH^-_{(aq)}$

C. $H_3O^+_{(aq)}$ and $HCO_3^-{}_{(aq)}$

D. $H_3O^+_{(aq)}$ and $OH^-_{(aq)}$

Use the following information to answer the next question.

The labels came off four cleaning solution containers found under a kitchen sink. Each of the cleaning solutions was tested with two available indicators, and the following results were recorded.

Cleaning Solution	Bromothymol blue	Phenolphthalein
1	blue	pink
2	blue	colourless
3	green	colourless
4	blue	light pink

Numerical Response

9. Listed in order from lowest to highest pH, the cleaning solutions are, respectively, _____ , _____ , _____ , and _____ .

(Record your **four-digit answer** in the numerical-response section on the answer sheet.)

Prairie Chem Inc. in Edmonton is a bulk manufacturer of concentrated bleach ($NaOCl_{(aq)}$). The bleach reacts with water to form a solution with a pH of 10.87.

$$OCl^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HOCl_{(aq)} + OH^-_{(aq)}$$

31. In this reaction, the substances that act as Brønsted–Lowry acids are

A. $OCl^-_{(aq)}$ and $H_2O_{(l)}$

B. $OCl^-_{(aq)}$ and $HOCl_{(aq)}$

C. $OCl^-_{(aq)}$ and $OH^-_{(aq)}$

D. $H_2O_{(l)}$ and $HOCl_{(aq)}$

32. The substance in the equation above that may act as an amphiprotic species is

A. $OCl^-_{(aq)}$

B. $H_2O_{(l)}$

C. $HOCl_{(aq)}$

D. $OH^-_{(aq)}$

33. The two species in equimolar amounts that could act as a buffer in this bleach solution are

A. $OCl^-_{(aq)}$ and $HOCl_{(aq)}$

B. $HOCl_{(aq)}$ and $OH^-_{(aq)}$

C. $OCl^-_{(aq)}$ and $H_2O_{(l)}$

D. $H_2O_{(l)}$ and $OH^-_{(aq)}$

34. In this bleach solution, the acid–base indicator

A. phenolphthalein would be colourless

B. alizarin yellow R would be orange

C. indigo carmine would be green

D. methyl orange would be red

Use the following information to answer the next question.

A bleach solution can be made by dissolving chlorine gas in a sodium hydroxide solution, as shown by the equation

$$Cl_{2(g)} + 2\,OH^-_{(aq)} \rightleftharpoons ClO^-_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)}$$

35. Mixing a bleach solution with an acid solution can be dangerous because it can cause

A. an increase in pH in the bleach solution

B. a shift in the equilibrium to the products

C. an increase in $Cl_{2(g)}$ concentration in the bleach solution

D. an increase in $Cl^-_{(aq)}$ concentration in the bleach solution

Use the following information to answer the next two questions.

> Coal is composed of many organic substances. When coal is mixed with water, acids are formed from the impurities found in the coal. Technicians at Elkview Coal Corporation refer to this mixture of acids as "humic acid."

36. A standard quality-control test involves the titration of monoprotic humic acid with $NaOH_{(aq)}$. If a 10.0 mL sample of a saturated solution of humic acid reacts with 15.9 mL of a 0.100 mol/L $NaOH_{(aq)}$ solution, then the concentration of the acid is

A. 0.0629 mol/L

B. 0.100 mol/L

C. 0.159 mol/L

D. 0.059 mol/L

*Use your recorded answer for **Multiple Choice 36** to answer **Multiple Choice 37.****

37. If the pH of a specific humic acid sample is 4.50, then the K_a value will be

A. 1.0×10^{-8}

B. 1.6×10^{-8}

C. 1.7×10^{-8}

D. 6.3×10^{-9}

***You can receive marks for this question even if the previous question was answered incorrectly.**

38. Chloroacetic acid ($CH_2ClCOOH_{(aq)}$) has a $K_a = 1.4 \times 10^{-3}$. This acid could best be described as a

A. weak inorganic acid
B. diprotic organic acid
C. weak monoprotic acid
D. strong monoprotic acid

39. In the equation $HNO_{3(aq)} + N_2H_{4(aq)} \rightleftharpoons NO_3^-{}_{(aq)} + N_2H_5^+{}_{(aq)}$, one conjugate acid–base pair is

A. $HNO_{3(aq)}$ and $N_2H_5^+{}_{(aq)}$
B. $HNO_{3(aq)}$ and $N_2H_{4(aq)}$
C. $N_2H_{4(aq)}$ and $N_2H_5^+{}_{(aq)}$
D. $N_2H_{4(aq)}$ and $NO_3^-{}_{(aq)}$

Use the following information to answer the next question.

A 0.500 mol/L solution of hydrazine ($N_2H_{4(aq)}$) contains the following equilibrium concentrations.

$$[N_2H_{4(aq)}] = 0.498 \text{ mol/L}$$

$$[OH^-_{(aq)}] = 2.14 \times 10^{-3} \text{ mol/L}$$

$$[N_2H_5{}^+_{(aq)}] = 2.14 \times 10^{-3} \text{ mol/L}$$

Numerical Response

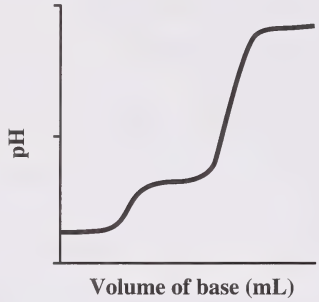
10. The K_b for hydrazine, in scientific notation, is $\boldsymbol{a.bc} \times 10^{-\boldsymbol{d}}$. The values of $\boldsymbol{a}$, $\boldsymbol{b}$, $\boldsymbol{c}$, and $\boldsymbol{d}$ are, respectively, _____, _____, _____, and _____.

(Record your **four-digit answer** in the numerical-response section on the answer sheet.)

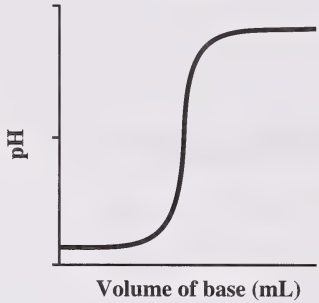
Use the following information to answer the next question.

When equally concentrated solutions of $HNO_{3(aq)}$, $CH_3COOH_{(aq)}$, $HOOCCOOH_{(aq)}$, and $Na_2S_{(aq)}$ were titrated with either a strong acid or strong base, the following titration curves were obtained.

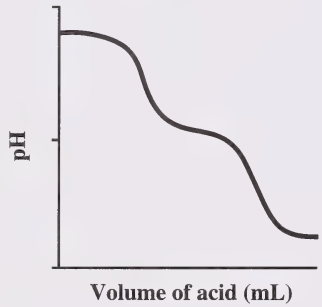
Graph 1



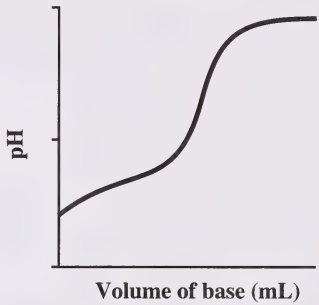
Graph 2



Graph 3



Graph 4



Numerical Response

11. Match each of the graphs, as numbered above, with the corresponding titration species listed below.

$HNO_{3(aq)}$ _____ (Record in the **first** column)

$CH_3COOH_{(aq)}$ _____ (Record in the **second** column)

$HOOCCOOH_{(aq)}$ _____ (Record in the **third** column)

$Na_2S_{(aq)}$ _____ (Record in the **fourth** column)

(Record your answer in the numerical-response section on the answer sheet.)

Use the following information to answer the next question.

The burning of methane in a Bunsen burner to produce energy can be represented by the equation

$$CH_{4(g)} + 2\,O_{2(g)} \rightarrow CO_{2(g)} + 2\,H_2O_{(g)}$$

40. A student determined that the reaction represented by the equation above is **not** at equilibrium because

A. the system is open

B. a catalyst is not present

C. the temperature is constant

D. both reactants and products are gases

---

41. Which of the following chemical changes would have the greatest percentage of products at equilibrium?

A. $AgCl_{(s)} \rightleftharpoons Ag^{+}_{(aq)} + Cl^{-}_{(aq)}$ $\quad K_{eq} = 2.0 \times 10^{-10}$

B. $BaCO_{3(s)} \rightleftharpoons Ba^{2+}_{(aq)} + CO_3{}^{2-}_{(aq)}$ $\quad K_{eq} = 5.5 \times 10^{-10}$

C. $HOBr_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^{+}_{(aq)} + OBr^{-}_{(aq)}$ $\quad K_{eq} = 2.1 \times 10^{-9}$

D. $NH_2OH_{(aq)} + H_2O_{(l)} \rightleftharpoons NH_3OH^{+}_{(aq)} + OH^{-}_{(aq)}$ $\quad K_{eq} = 1.1 \times 10^{-8}$

The production of paper can involve the reaction of the hydrated aluminum ion $Al(H_2O)_6^{3+}{}_{(aq)}$ with water.

$$Al(H_2O)_6^{3+}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons Al(OH)(H_2O)_5^{2+}{}_{(aq)} + H_3O^+{}_{(aq)} \qquad K_a = 1.4 \times 10^{-5}$$

42. The acid dissociation expression for this system is

A. $K_a = \dfrac{[Al(OH)(H_2O)_5^{2+}{}_{(aq)}]}{[Al(H_2O)_6^{3+}{}_{(aq)}]}$

B. $K_a = \dfrac{[Al(OH)(H_2O)_5^{2+}{}_{(aq)}][H_3O^+{}_{(aq)}]}{[Al(H_2O)_6^{3+}{}_{(aq)}][H_2O_{(l)}]}$

C. $K_a = \dfrac{[Al(OH)(H_2O)_5^{2+}{}_{(aq)}]}{[Al(H_2O)_6^{3+}{}_{(aq)}][H_2O_{(l)}]}$

D. $K_a = \dfrac{[Al(OH)(H_2O)_5^{2+}{}_{(aq)}][H_3O^+{}_{(aq)}]}{[Al(H_2O)_6^{3+}{}_{(aq)}]}$

*Use your recorded answer for **Multiple Choice 42** to answer **Multiple Choice 43.****

43. The hydronium ion concentration in a 0.585 mol/L $Al(H_2O)_6^{3+}{}_{(aq)}$ solution is

A. 8.2×10^{-6} mol/L

B. 2.4×10^{-5} mol/L

C. 4.9×10^{-3} mol/L

D. 2.9×10^{-3} mol/L

***You can receive marks for this question even if the previous question was answered incorrectly.**

*Use your recorded answer for **Multiple Choice 43** to answer **Numerical Response 12.****

Numerical Response

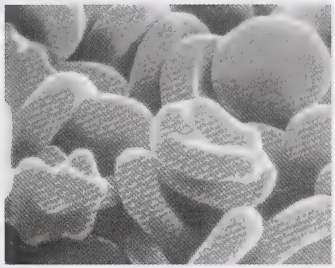
12. The pH of this aluminum ion solution is _____.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

***You can receive marks for this question even if the previous question was answered incorrectly.**

Use the following information to answer the next question.

Red Blood Cells



—From *Chemistry: Molecules, Matter, and Change*, Third Edition

Three Important Equilibria in Blood

$$\underset{\text{hemoglobin}}{HHb^{+}_{(aq)}} + O_{2(g)} \rightleftharpoons \underset{\text{oxyhemoglobin}}{HbO_{2(aq)}} + H^{+}_{(aq)}$$

$$H^{+}_{(aq)} + HCO_3^{-}{}_{(aq)} \rightleftharpoons H_2CO_{3(aq)}$$

$$H_2CO_{3(aq)} \rightleftharpoons CO_{2(g)} + H_2O_{(l)}$$

44. In blood, the $[H^{+}_{(aq)}]$ could be increased by decreasing the

A. $[CO_{2(g)}]$

B. $[O_{2(g)}]$

C. $[HCO_3^{-}{}_{(aq)}]$

D. $[H_2CO_{3(aq)}]$

The written-response questions follow on the next page.

Use the following information to answer the next question.

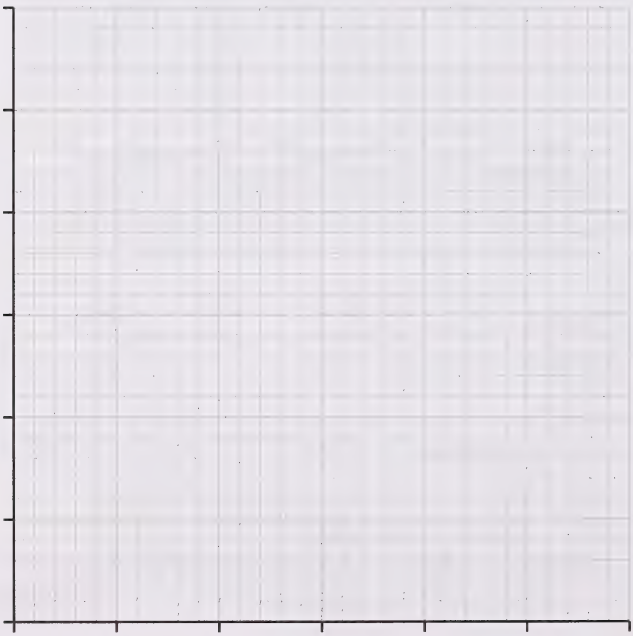
Most arenas and curling rinks have artificial ice. Many ice-making plants use ammonia as the refrigerant. The ammonia is circulated in pipes under the ice of the arena or curling rink. For this question, assume that the **only** changes to the ammonia are represented in the equilibrium

$$NH_{3(l)} \rightleftharpoons NH_{3(g)} \qquad \Delta H = +23.3 \text{ kJ}$$

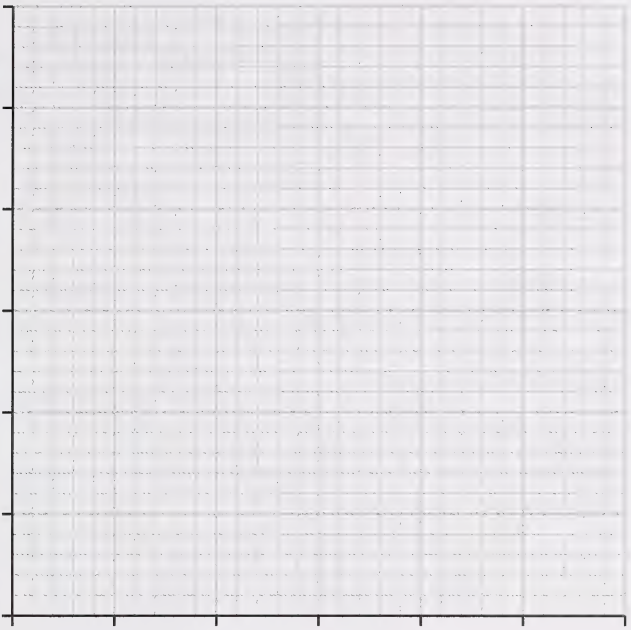
Written Response—15%

1. **a.** On the axes provided, draw and label, as precisely as possible, the graphs that represent the energy changes that occur to the ammonia below the ice surface and to the water on the ice surface as the refrigeration system operates. Assume that the water applied to the ice surface is initially at 20.00°C.

Ammonia Change



Water Change



b. What mass of ammonia must undergo a phase change in order to change 1.00×10^7 g (10.0 kL) of water at 20.00°C to ice at 0.00°C?

Use the following information to answer the next question.

The formation of a pollutant gas, nitrogen monoxide ($NO_{(g)}$), by the reaction of nitrogen with oxygen in a gasoline engine can be affected by changing the combustion temperature within the engine. The equilibrium constant for the production of one mole of $NO_{(g)}$ at 25°C is 1.0×10^{-17}.

Written Response—15%

2. Explain how an increase in temperature could affect the concentration of the pollutant gas and the equilibrium constant.

Your response should also include

- relevant chemical equation(s) and values from the chemistry data booklet
- a description of two ways that car manufacturers could reduce the $NO_{(g)}$ emissions in new model vehicles

You have now completed the examination.
If you have time, you may wish to check your answers.

Credits

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